

WHAT IS CLAIMED IS:

1. An apparatus comprising:  
an implantable housing, the implantable housing comprising:  
a thoracic monitor circuit, including an output to provide time domain thoracic information; and  
a signal processor circuit, the signal processor circuit comprising:  
a time-to-frequency domain converter circuit, including an input coupled to the thoracic monitor circuit output to receive the time domain thoracic information, and including an output providing frequency domain thoracic information; and  
a spectrum analyzer circuit, including a input coupled to the time-to-frequency domain converter circuit output to receive the frequency domain thoracic information, and including an output to provide a classification of a pulmonary physiological state using a respiration component of the frequency-domain thoracic information.
2. The apparatus of claim 1, in which the thoracic monitor circuit comprises an impedance detector circuit.
3. The apparatus of claim 2, in which the impedance detector circuit comprises:  
a test stimulus circuit, configured to be coupled to a subject using implantable electrodes to deliver a test stimulus to the subject; and  
a response sensing circuit, configured to be coupled to the subject using implantable electrodes to receive a signal correlative to transthoracic impedance in the subject in response to the test stimulus delivered to the subject.

4. The apparatus of claim 1, in which the thoracic monitor circuit comprises an acceleration detector circuit.
5. The apparatus of claim 1, in which the thoracic monitor circuit comprises an analog-to-digital (A/D) converter circuit.
6. The apparatus of claim 1, in which the time-to-frequency domain converter circuit comprises a fast-Fourier transform (FFT) module.
7. The apparatus of claim 1, further comprising:
  - a controller circuit, the controller circuit comprising an input coupled to the spectrum analyzer output to receive the pulmonary physiological state classification;
  - and
  - a therapy circuit, coupled to the controller circuit, to deliver therapy to the subject using the pulmonary physiological state classification.
8. The apparatus of claim 1, further including a telemetry circuit, coupled to the output of the spectrum analyzer to receive the pulmonary physiological state classification for communication from the implantable housing.
9. The apparatus of claim 1, in which the spectrum analyzer is configured to compute a physiological indicator using a heart rate variability (HRV) component of the frequency-domain thoracic information.
10. The apparatus of claim 1, further comprising a frequency domain adaptive filter, the frequency domain adaptive filter comprising a first input coupled to the output of the time-to-frequency domain converter circuit, the frequency domain

adaptive filter also comprising an output coupled to the input of the spectrum analyzer.

11. The apparatus of claim 10, further comprising:

a depolarization detector circuit; and

a heart rate interval timer circuit, coupled to the depolarization detector circuit, the heart rate interval timer circuit including an output coupled to a second input of the frequency domain adaptive filter.

12. The apparatus of claim 1, in which the signal processor circuit includes a digital signal processor (DSP) circuit.

13. An apparatus comprising:

an implantable housing, the implantable housing comprising:

a thoracic monitor circuit, including an output to provide time domain thoracic information; and

a signal processor circuit, the signal processor circuit comprising:

a time-to-frequency domain converter circuit, including an input coupled to the thoracic monitor circuit output to receive the time domain thoracic information, and including an output providing frequency domain thoracic information; and

a frequency domain adaptive filter, the frequency domain adaptive filter including a first input coupled to the output of the time-to-frequency domain converter circuit, the frequency domain adaptive filter including a second input to receive a time domain heart rate signal, the frequency domain adaptive filter configured to distinguish a respiration component of the frequency domain thoracic

information from a heart contraction component of the frequency domain thoracic information.

14. The apparatus of claim 13, in which the thoracic monitor circuit comprises an impedance detector circuit.

15. The apparatus of claim 14, in which the impedance detector circuit comprises:

a test stimulus circuit, configured to be coupled to a subject using implantable electrodes to deliver a test stimulus to the subject; and

a response sensing circuit, configured to be coupled to the subject using implantable electrodes to receive a signal correlative to transthoracic impedance in the subject in response to the test stimulus delivered to the subject.

16. The apparatus of claim 13, in which the thoracic monitor circuit comprises an acceleration detector circuit.

17. The apparatus of claim 13, in which the thoracic monitor circuit comprises an analog-to-digital (A/D) converter circuit.

18. The apparatus of claim 13, in which the time-to-frequency domain converter circuit comprises a fast-Fourier transform (FFT) module.

19. The apparatus of claim 13, in which the signal processor circuit comprises a spectrum analyzer circuit, the spectrum analyzer circuit including an input coupled to the time-to-frequency domain converter circuit output to receive the frequency domain thoracic information, and the spectrum analyzer including an output to

provide a classification of a pulmonary physiological state using a respiration component of the frequency-domain thoracic information.

**20.** The apparatus of claim 19, further comprising:

a controller circuit, the controller circuit including an input coupled to the spectrum analyzer output to receive the pulmonary physiological state classification; and

a therapy circuit, coupled to the controller circuit, to deliver therapy to the subject using the pulmonary physiological state classification.

**21.** The apparatus of claim 19, further comprising a telemetry circuit, coupled to the output of the spectrum analyzer to receive the pulmonary physiological state classification for communication from the implantable housing.

**22.** The apparatus of claim 19, in which the spectrum analyzer computes a physiological indicator using a heart rate variability (HRV) component of the frequency-domain thoracic information.

**23.** The apparatus of claim 13, further comprising:

a depolarization detector circuit; and

a heart rate interval timer circuit, coupled to the depolarization detector circuit, the heart rate interval timer circuit including an output coupled to a second input of the frequency domain adaptive filter.

**24.** The apparatus of claim 13, in which the signal processor circuit includes a digital signal processor (DSP) circuit.

**25.** A method comprising:

detecting a time domain thoracic signal using an implanted device;  
transforming the time domain thoracic signal into a frequency-domain  
thoracic signal;  
filtering the frequency domain thoracic signal in the frequency domain to  
obtain frequency domain respiration information; and  
classifying a pulmonary physiological state using the frequency domain  
respiration information

**26.** The method of claim **25**, in which the detecting the time domain thoracic signal comprises detecting an impedance.

**27.** The method of claim **25**, in which the detecting the time domain thoracic signal comprises detecting an acceleration.

**28.** The method of claim **25**, in which the transforming the time domain thoracic signal comprises using the implanted device.

**29.** The method of claim **25**, in which the filtering comprises using the implanted device.

**30.** The method of claim **25**, in which the classifying a pulmonary physiological state includes using the implanted device.

**31.** The method of claim **25**, in which the transforming the time domain thoracic signal comprises performing a fast Fourier transform (FFT).

32. The method of claim 25, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of normal respiration.
33. The method of claim 25, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of periodic respiration.
34. The method of claim 25, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of Cheyne-Stokes respiration.
35. The method of claim 25, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of obstructed respiration.
36. The method of claim 25, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of restrictive respiration.
37. The method of claim 25, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of pulmonary fluid accumulation.
38. The method of claim 25, further comprising communicating information about the pulmonary physiological state from the subject to a remote interface.

39. The method of claim 38, further comprising storing the pulmonary physiological state for a predetermined time in a non-implanted memory.
40. The method of claim 39, further comprising displaying a trend of stored pulmonary physiological states.
41. A method comprising:  
detecting a time domain thoracic signal using an implanted device;  
detecting a heart rate;  
transforming the time domain thoracic signal into a frequency domain thoracic signal; and  
filtering the frequency domain thoracic signal in the frequency domain using a cutoff frequency that varies as a function of the detected heart rate.
42. The method of claim 41, in which the detecting the time domain thoracic signal includes detecting an impedance signal.
43. The method of claim 41, in which the detecting the time domain thoracic signal includes detecting an acceleration signal.
44. The method of claim 41, in which the transforming the time domain thoracic signal comprises performing a fast Fourier transform (FFT).
45. The method of claim 41, in which the filtering includes extracting heart rate contraction information from the frequency domain thoracic signal.
46. The method of claim 41, in which the filtering includes extracting respiration information from the frequency domain thoracic signal.



**47.** The method of claim 46, further comprising classifying a pulmonary physiological state using the respiration information.

**48.** The method of claim 47, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of normal respiration.

**49.** The method of claim 47, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of periodic respiration.

**50.** The method of claim 47, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of Cheyne-Stokes respiration.

**51.** The method of claim 47, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of obstructed respiration.

**52.** The method of claim 47, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of restrictive respiration.

**53.** The method of claim 47, in which the classifying the pulmonary physiological state includes classifying the pulmonary physiological state as indicative of pulmonary fluid accumulation.

**54.** The method of claim **47**, further comprising communicating information about the pulmonary physiological state from within the subject to a remote interface.